THE NUTRIENT STATUS OF A CHEROKEE SILT LOAM SOIL AFTER LONG-TIME APPLICATION OF FERTILIZERS, LIME, AND MANURE

by

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TABLE OF CONTENTS

INTRODUCTION

Long-time fertility studies using planned rotations and soil treatments can provide much information of value to the agricultural economy of an area. One aim of agriculture must, of necessity, be to maintain, if not improve, the fertility of the soil. A complete evaluation of specific treatments and practices cannot be accurately determined from the data of any one year; it is only through long-time studies that a valid picture can be obtained.

Many such studies have been instituted in various parts of the world in years past. Some have been continued to the present day. At the Rothamsted Experimental Station there are plots that have been in continuous fertility studies since the founding of the field in 1843 (8). This has also been true at the Woburn Experimental Station where work has continued since 1876 (11). In the United States the Jordan Plots (9, 12, 18) at Pennsylvania State College were established in 1881 and have been maintained as originally designed up to the present. Similar fields are in existence, although for relatively shorter periods of time, in Illinois (4), Indiana (13), Kentucky (15, 16, 17), and Missouri (14).

The Columbus Fertility Plots represent one of the oldest continuous fertility studies in Kansas. Since its inception in 1924 the program has been carried on with only minor changes in rotation and in amount and method of application of fertilizers.

The experiment was designed to study the effect of various

fertilizer materials, lime, and manure on a rotation consisting of the important crops of the area.

With twenty-eight years of fertilizer treatments and management practices as a background the present study was undertaken in an effort to learn something of the resultant nutrient status of these soils.

DESCRIPTION OF THE FIELD

Location

The Columbus Fertility Plots are located on the W. H. Shaffer farm, 2 miles west and 3 miles north of Columbus in Cherokee county in southeastern Kansas.

Soils

The soil of the Columbus Fertility Plots is, for the most part, a Cherokee silt loam, having a white ashy surface, a very heavy dark grey subsurface, and an impervious drab colored subsoil flecked with red, yellow and grey.

Layout

The fertility plots were laid out systematically in six series running from east to west and designated by letter A through F. Each series was further subdivided into twelve one-tenth acre plots numbered consecutively from north to south 1 through 12.

Rotations

At the outset of the experiment the rotation followed was:

1. corn
2. oats, sweet clover seeded with oats
3. sweet clover or cowpeas as green manure
4. wheat
5. wheat
6. alfalfa

Alfalfa always occurred on one series. It was allowed to remain as long as a reasonably good stand was maintained. This has varied for the various series from three to five years. When a series was taken out of alfalfa it replaced another series in the five-year rotation; the series removed from the rotation was then seeded to alfalfa.

In 1931 it was desired to include flax and soybeans in the rotation. Consequently the rotation was changed as of that year to:

1. corn
2. soybeans for grain
3. flax
4. wheat
5. oats and sweet clover as a spring green manure crop
6. alfalfa

This rotation has been maintained until the present.

Plot 10 of each series has never grown a legume. This was intended to permit evaluation of the effect of a legume in the

rotation. When a series was in soybeans grain sorghum was substituted on plot 10; when in oats and sweet clover the sweet clover was omitted on plot 10; when in alfalfa redtop or bromegrass was substituted on plot 10.

The cropping sequence for each series since the start of the experiment in 1924 appears in Table 1.

Soil Treatments

The plots have received the following treatments:

plot 1. lime

plot 2. lime and superphosphate

plot 3. lime, superphosphate, and potash

plot 4. lime and rock phosphate

plot 5. lime, superphosphate, and since 1947 magnesium

plot 6. lime and manure

plot 7. lime, superphosphate and manure

plot 8. lime, superphosphate, and, since 1947 boron

plot 9N. lime, manure, and rock phosphate

plot 9S. lime, manure, and, since 1947 residual rock phosphate

plot 10. lime and superphosphate with no legume in the rotation

plot 11. lime and superphosphate

plot 12. no treatment

Originally plots 2, 5, 8, and 11, each receiving the same treatment, lime and superphosphate, were intended to serve as

Table 1. Sequence of crops grown at the Columbus Experiment Field, 1924-52, inclusive.

Year	Series A	Series B	Series C	Series D	Series E	Series F
1952	flax	wheat	soybeans	corn	oats&sw.cl.*	alfalfa
1951	soybeans	flax	corn	oats&sw.cl.	alfalfa	wheat
1950	corn	soybeans	oats&sw.cl.	wheat	alfalfa	flax
1949	alfalfa	corn	wheat	flax	oats	soybeans
1948	alfalfa	oats&sw.cl.	flax	soybeans	wheat	corn
1947	alfalfa	wheat	soybeans	corn	flax	oats&sw.cl.
1946	alfalfa	flax	corn	oats&sw.cl.	soybeans	soybeans
1945	oats&sw.cl.	soybeans	alfalfa	wheat	corn	flax
1944	wheat	corn	alfalfa	flax	oats&sw.cl.	soybeans
1943	flax	oats&sw.cl.	alfalfa	soybeans	wheat	sorghum
1942	soybeans	oats	alfalfa	corn	flax	oats&sw.cl.
1941	corn	flax	oats&sw.cl.	alfalfa	soybeans	wheat
1940	oats 7 sw.cl.	soybeans	wheat	alfalfa	corn	flax
1939	wheat	corn	flax	alfalfa	oats&sw.cl.	soybeans
1938	flax	alfalfa	soybeans	oats&sw.cl.	wheat	corn
1937	soybeans	alfalfa	corn	wheat	flax	oats&sw.cl.
1936	corn	alfalfa	oats&sw.cl.	flax	soybeans	wheat
1935	oats&sw.cl.	alfalfa	wheat	no crop	corn	flax
1934	wheat	oats&sw.cl.	flax	corn	alfalfa	soybeans
1933	flax	wheat	soybeans	oats&sw.cl.	alfalfa	kafir
1932	soybeans	flax	corn	wheat	alfalfa	oats&sw.cl.
1931	corn	soybeans	oats&sw.cl.	flax	alfalfa	wheat
1930	oats&sw.cl.	corn	wheat	wheat	alfalfa	flax
1929	kafir	wheat	wheat	sw.cl.	oats	alfalfa
1928	wheat	wheat	sw.cl.	oats	corn	alfalfa
1927	wheat	sw.cl.	sw.cl.	corn	wheat	alfalfa
1926	cowpeas	oats&sw.cl.	corn	wheat	wheat	alfalfa
1925	oats&sw.cl.	corn	wheat	wheat	cowpeas	alfalfa
1924	corn	oats	oats	cowpeas	fallow	alfalfa

*sw. cl. will be used as an abbreviation for sweet clover in this table.

check plots to reveal soil variations. In 1947 it was decided to include magnesium and boron in the study. Plots 5 and 8 respectively were selected for the magnesium and boron treatments, leaving plots 2 and 11 as check plots.

Inasmuch as the study herein reported was intended to consider the effect of long-time treatments the magnesium and boron treatments, which had been in effect for only five years, were not included.

Also in 1947, plot 9, which had originally received lime, manure, and rock phosphate, was divided in half; one half, designated as 9N, was to continue to receive the original treatment; the other half, designated as 9S, was to have no further applications of rock phosphate.

Rate and Method of Application of the Various Materials

Lime. Limestone was originally supplied at the rate of 3 tons per acre the first time a series was seeded to alfalfa or sweet clover. The liming history for each series appears in Table 2.

Barnyard Manure. Barnyard manure at the rate of 8 tons per acre was applied to those plots scheduled for that treatment. Application was made once per rotation; preceding corn during the period 1924 to 1930, preceding wheat since 1931. Application was also made prior to the seeding of alfalfa. No record was kept as to the quality of the manure added.

Superphosphate. The rate and method of application of

Table 2. History of applications of limestone at the Columbus fertility experiment.

Series	Year	Am't of limestone applied (tons/A)
A	1925 1945	3.0 1.5
B	1929 1935	3.0 1.5
C	1927 1941	3.0 1.5
D	1928 1933 1938	3.0 1.0 1.5
E	1923 1924	3.0 3.0
F	1923 1924 1925	3.0 3.0 3.0

superphosphate was changed several times for the various crops curing the years of the experiment. Prior to 1930 superphosphate was broadcast at the rate of 50 pounds of 0-16-0 per acre for corn and oats and 100 pounds of 0-16-0 per acre for wheat before seeding. In 1930 the method of application was changed in that superphosphate was drilled with the seed for wheat and oats. In 1931 superphosphate was dropped in the hill with corn. Flax was added to the rotation in this year and superphosphate was drilled with the seed at the rate of 100 pounds of 0-16-0 per acre. Direct application of superphosphate to the soybean crop began in 1934 at the rate of 50 pounds of 0-16-0 per acre drilled with the seed. In 1941 the rate of application of superphosphate on

flax was reduced from 100 pounds to 50 pounds; the rate of application on oats was increased from 50 pounds to 100 pounds. Alfalfa received superphosphate annually at the rate of 150 pounds of 0-16-0 per acre as a broadcast application. When it was necessary to use a grade other than 0-16-0 the amount applied was adjusted so as to supply an equivalent amount of available phosphoric acid.

In 1947 the rate of application of superphosphate on all crops was increased. The new rates were 100 pounds of 0-20-0 per acre on corn, flax, and soybeans; 150 pounds of 0-20-0 per acre on oats and wheat; and 200 pounds of 0-20-0 per acre on alfalfa. These rates have been maintained until the present.

Potash. Muriate of potash, in combination with lime and superphosphate, has been applied only to plot 3 of each series. The original rate of application, which was quite low, was increased on two occasions. The ratio of P_2O_5 to K_2O during the years of the experiment was as follows:

1924 - 1928	0-6-1
1929 - 1946	0-3-1
since 1947	0-1-1

Rock Phosphate. Rock phosphate was applied where scheduled at the rate of 1000 pounds per acre. Application was made either before seeding alfalfa or broadcast on the green manure crop before plowing under.

SOIL ANALYSES

Sampling

In July of 1952 soil samples were taken from the plots in

the six series by E. A. Cleavinger, extension agronomist.

Samples were taken at three depths, 0-6 inches, 6-8 inches, 8-10 inches. Consideration was given to the soil profile in deciding on these depths.

A soil sampling tube was used. Five holes were made at random in each plot and composited for the plot sample. This was done for each of the three depths.

The samples were brought to the Agronomy department laboratory and were permitted to air-dry for about two weeks. The soil was ground so as to pass a 2 mm sieve.

Determinations

The laboratory determinations included:

1. pH of a 1:1 soil:water suspension
2. available phosphorus
   a. using an extracting solution 0.1 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride.
   b. using an extracting solution 0.025 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride.
3. exchangeable potassium
4. organic matter
5. total nitrogen

Procedures

Soil reaction. The pH determinations were made on a Leeds-Northrup instrument using the glass electrode. Duplicate ten gram samples were weighed into paper cups, 10 ml of distilled water was added and the mixture stirred vigorously. After thirty minutes the material was again stirred and the pH of the suspension was read immediately.

Available phosphorus. A modification of Bray's sulphonic acid reduction method as reported by Arnold and Kurtz (2) was used. According to Bray and Kurtz (5) there are various fractions of the soil phosphorus that can be determined depending upon the extracting solution used. For this work two separate extracting solutions were employed: one, which was 0.1 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride, removes, according to Bray, the acid soluble and adsorbed phosphorus; the other, which was 0.025 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride, removes, according to Bray, the so-called adsorbed phosphorus.

In each case duplicate 5 gram samples where shaken for one minute with 50 ml of the extracting solution and filtered immediately. A 20 ml aliquot was taken. One ml each of ammonium molybdate-hydrochloric acid solution and Bray's sulfonic acid reducing agent were added. Color was allowed to develop for fifteen minutes at which time per cent transmittancy was read on the Evelyn photocletric colorimeter using a 660 mu filter. A

calibration was prepared from standard phosphate solutions given the same treatment as the unknowns. From this curve the per cent transmittancy of the unknown samples was converted to ppm.

Organic matter. Walkley and Black's titration method as reported by Piper (10) was used. Duplicate 2 gram samples of soil were digested for 30 minutes with 10 ml of standard potassium dichromate solution and 20 ml of concentrated sulfuric acid. The excess chromate not reduced by the organic matter was determined by titration with standard ferrous sulphate solution to the diphenylamine endpoint.

Total nitrogen. The official Kjeldahl method as given in the A. O. A. C. methods of Analyses (3) was used for the determination of total nitrogen.

Exchangeable potassium. For the determination of exchangeable potassium duplicate 10 gram samples were shaken for 10 minutes with 50 ml of normal neutral ammonium acetate and filtered immediately. A 5 ml aliquot was taken and diluted to 25 ml. Per cent transmittancy was read on the Bechman spectrophotometer using a flame attachment with a wavelength setting of 771 mu and a slit width of 0.1. A calibration curve was prepared from known potassium standard solutions. From this curve per cent transmittancy readings of the samples were converted to ppm.

Results

The results of the chemical analyses are reported in Tables 3 to 8, inclusive. The value at each depth for each plot has been recorded as well as the averages of all series for each treatment. These averages of all series also are presented graphically in Figs. 1 to 6, inclusive.

Discussion

Since the field was arranged systematically, with no attempt at randomization, the ordinary methods of statistical analysis were not applicable. Therefore no statistical analysis of the data was undertaken.

The data for the individual plots were carefully scrutinized in an attempt to observe trends that could be attributed to treatment, always remaining cognizant of the fact that soil variation had very likely influenced the data.

The average of each treatment for all series was compiled with the hope that a reasonably valid picture of treatment effects would be obtained.

<u>The Effect of Additions of Limestone on Soil Reaction</u>. The effectiveness of limestone in raising the pH value of the soil was demonstrated in all cases and at all depths. The greatest increase has been in the surface layer but the effect has quite definitely extended on to the 10 inch depth. Figure 1 reveals the south end of the field, plots 9S, 9N, 10, and 11 to be less acid than the north end, and quite uniformly so. This may well

Table 3. The pH values of soil of various fertility plots at the Columbus Experiment Field, 1952.

Series	Depth (in.)	1	2	3	4	6	7	9S	9N	10	11	12
		pH status of various plots										
A	0-6	6.0	6.5	6.0	6.4	5.9	6.0	6.3	6.5	6.4	6.2	5.3
	6-8	6.2	6.4	6.0	6.3	5.6	6.1	5.9	6.4	6.0	5.8	5.1
	8-10	5.8	5.6	5.7	6.0	5.7	5.8	5.8	6.2	5.9	5.4	5.1
B	0-6	5.9	6.0	6.6	6.0	6.2	5.9	6.4	6.1	6.4	6.1	5.4
	6-8	5.8	5.7	5.8	5.7	5.7	5.7	5.8	6.1	6.0	5.8	5.4
	8-10	5.4	5.5	5.6	5.7	5.6	5.5	5.6	5.8	5.7	5.5	5.2
C	0-6	5.7	5.7	5.6	5.8	5.7	5.7	5.8	5.8	5.8	5.7	5.1
	6-8	5.6	5.4	5.6	5.6	5.6	5.5	5.7	5.6	5.6	5.5	5.1
	8-10	5.5	5.3	5.4	5.3	5.3	5.3	5.4	5.3	5.4	5.2	5.1
D	0-6	6.3	6.3	6.2	6.4	6.1	6.2	6.4	6.3	6.4	6.4	5.2
	6-8	5.9	5.7	5.8	6.0	5.8	6.0	5.9	5.9	6.0	6.1	5.3
	8-10	5.6	5.6	5.5	5.6	5.5	5.7	5.6	5.8	5.6	5.8	5.3
E	0-6	5.9	5.9	5.9	6.0	5.7	6.0	5.9	6.0	6.2	6.5	5.5
	6-8	5.8	5.9	5.9	6.0	5.6	5.7	5.9	6.0	6.0	6.5	5.5
	8-10	5.7	5.6	5.7	5.8	5.5	6.0	5.7	5.9	6.0	6.3	5.5
F	0-6	7.0	7.0	6.6	7.2	7.3	7.4	7.5	7.5	7.4	7.5	5.2
	6-8	6.6	6.8	6.2	6.9	7.3	7.0	7.4	7.3	7.5	6.5	5.3
	8-10	6.2	6.3	5.9	6.6	7.1	7.0	7.2	7.4	7.4	6.1	5.3
		AVERAGE OF SERIES										
	0-6	6.1	6.2	6.1	6.3	6.1	6.2	6.4	6.4	6.4	6.4	5.3
	6-8	6.0	6.0	5.9	6.1	5.9	6.0	6.1	6.2	6.2	6.0	5.3
	8-10	5.8	5.7	5.6	5.8	5.8	6.0	5.9	6.1	6.0	5.7	5.2

Table 4. Available phosphorus content of various fertility plots at the Columbus Experiment Field, 1952, as measured by extraction with 0.1 N HCl and 0.03 N NH_4F.

Series	Depth (in.)	Pounds of available phosphorus per acre in various plots										
		1	2	3	4	6	7	9S	9N	10	11	12
A	0-6	10.4	34.1	32.2	384.0	36.0	39.5	306.0	336.0	66.4	46.4	15.0
	6-8	8.0	32.6	21.6	276.0	7.8	15.4	140.0	168.0	17.0	15.4	8.4
	8-10	4.4	11.5	11.2	138.0	5.6	8.6	21.0	32.2	10.2	11.6	7.4
B	0-6	10.6	25.6	37.2	264.0	13.6	32.2	192.0	328.0	44.2	61.6	10.0
	6-8	7.0	13.4	16.2	30.8	6.4	8.8	7.8	28.6	8.0	9.6	5.1
	8-10	6.0	6.6	6.6	22.0	6.8	7.6	19.2	22.0	5.8	7.2	4.6
C	0-6	11.6	21.6	20.6	264.0	14.0	35.0	280.0	200.0	36.0	21.5	7.8
	6-8	6.8	12.0	12.2	140.0	6.5	8.0	80.0	103.0	18.0	10.0	6.3
	8-10	5.8	10.5	9.0	22.0	5.3	6.0	22.0	18.5	7.0	6.0	4.0
D	0-6	19.0	21.0	26.5	320.0	35.0	47.0	310.0	355.0	44.0	27.0	12.0
	6-8	16.0	18.2	8.8	21.2	15.5	19.0	17.8	13.4	10.6	9.0	9.8
	8-10	15.8	4.4	7.5	14.4	16.5	10.8	12.6	13.6	6.6	7.3	10.5
E	0-6	13.6	32.0	45.0	332.0	16.7	59.6	448.0	400.0	47.4	37.8	8.6
	6-8	9.0	10.8	10.8	35.0	7.8	16.0	74.2	70.0	17.4	15.6	6.4
	8-10	6.4	6.6	5.8	8.6	5.4	27.6	18.0	37.8	10.6	10.2	5.8
F	0-6	15.2	31.5	39.0	644.0	23.8	44.2	452.0	386.0	42.8	29.7	7.6
	6-8	10.2	10.3	14.7	33.0	13.6	16.4	194.0	230.0	16.2	12.9	4.4
	8-10	11.5	8.8	9.3	43.6	9.2	9.2	26.8	30.0	10.9	10.6	4.0
AVERAGE OF SERIES												
	0-6	13.4	27.6	16.7	368.0	23.1	43.0	331.0	334.0	46.8	37.3	10.1
	6-8	9.5	16.2	14.0	89.0	9.6	14.0	68.9	102.0	14.5	12.0	6.7
	8-10	8.3	8.0	8.2	41.4	8.1	11.6	19.8	26.0	8.5	8.8	6.0

Table 5. Available phosphorus content of various fertility plots at the Columbus Experiment Field, 1952, as measured by extraction with 0.025 N HCl and 0.03 N NH_4F.

Series	Depth (in.)	Pounds of available phosphorus per acre in various plots: 1	2	3	4	6	7	9S	9N	10	11	12
A	0-6	6.4	16.7	14.6	12.3	24.0	23.6	15.6	20.2	27.0	25.4	10.2
	6-8	5.6	15.8	8.8	9.2	6.0	10.4	8.8	9.8	9.6	10.8	6.2
	8-10	3.6	6.2	5.6	6.4	6.0	5.8	6.0	7.6	6.8	8.2	6.0
B	0-6	6.4	11.6	13.6	8.0	7.8	18.2	17.0	12.6	18.8	14.7	6.8
	6-8	4.8	7.4	7.0	4.6	3.8	3.4	4.4	5.0	5.4	7.2	4.1
	8-10	4.8	5.4	4.8	4.6	5.0	3.4	6.0	5.0	5.8	5.8	5.2
C	0-6	10.4	16.4	12.9	17.6	15.3	17.0	19.0	10.0	17.7	12.6	6.8
	6-8	7.5	11.2	12.3	12.2	11.2	11.7	6.8	7.2	9.2	6.6	4.8
	8-10	6.8	7.0	6.2	7.6	7.2	7.2	6.0	6.0	5.5	5.1	4.2
D	0-6	7.6	13.0	12.0	12.9	21.8	25.0	22.6	20.3	24.0	17.8	9.6
	6-8	6.0	7.0	6.2	6.9	10.0	11.3	9.3	8.0	9.0	9.0	6.6
	8-10	6.4	3.8	6.2	4.6	8.0	7.6	8.0	6.2	6.2	6.6	6.0
E	0-6	7.4	13.2	17.7	11.8	10.2	28.8	16.6	15.4	25.2	17.8	7.6
	6-8	5.4	6.6	7.0	6.2	5.0	8.0	8.0	9.0	10.6	11.6	5.8
	8-10	4.8	5.4	5.2	4.8	4.8	6.8	6.4	8.6	7.6	8.4	5.2
F	0-6	9.6	18.5	18.4	12.1	12.4	23.6	11.9	10.6	18.7	14.7	6.6
	6-8	8.0	8.8	7.7	7.5	8.0	10.4	9.3	8.1	9.4	7.6	4.4
	8-10	7.3	6.6	6.6	6.3	7.2	7.6	7.6	7.5	2.0	7.3	3.6
AVERAGE OF SERIES												
	0-6	8.0	14.9	14.8	12.4	15.2	22.7	17.1	14.8	21.9	17.1	7.9
	6-8	6.2	9.4	8.1	7.7	7.3	14.3	7.7	7.8	9.0	8.8	5.3
	8-10	5.6	5.7	5.7	5.7	6.3	6.4	6.6	5.9	6.5	6.6	5.0

Table 6. Exchangeable potassium content of various fertility plots at the Columbus Experiment Field, 1952.

Series	Depth (in.)	Pounds of exchangeable K per acre in various plots										
		1	2	3	4	6	7	9S	9N	10	11	12
A	0-6	63	79	89	117	193	97	83	156	77	86	111
	6-8	70	77	84	100	88	87	68	174	71	77	92
	8-10	75	69	70	96	77	75	70	73	62	76	87
B	0-6	89	99	125	103	128	120	142	144	122	96	103
	6-8	95	103	104	91	108	110	150	140	132	93	95
	8-10	93	89	89	88	107	135	161	162	119	93	88
C	0-6	99	95	108	84	96	110	93	92	90	73	74
	6-8	108	95	103	92	87	95	93	82	86	72	80
	8-10	92	86	87	80	73	93	87	113	92	86	74
D	0-6	84	119	134	127	198	171	152	148	103	103	117
	6-8	76	107	109	144	129	112	112	105	103	100	107
	8-10	78	90	99	102	123	115	99	106	82	90	93
E	0-6	94	92	118	107	104	108	103	99	75	74	70
	6-8	95	96	111	112	90	92	86	83	81	80	82
	8-10	92	90	107	116	92	79	75	75	74	76	82
F	0-6	114	104	100	101	109	97	91	100	84	69	69
	6-8	185	134	120	112	120	96	102	120	91	85	77
	8-10	188	166	141	107	115	93	97	120	86	69	76
AVERAGE OF SERIES												
	0-6	92	98	112	105	136	116	110	106	92	83	90
	6-8	105	102	103	103	106	101	102	117	95	84	89
	8-10	103	88	99	98	98	98	98	108	86	81	83

Table 7. Organic matter content of various fertility plots at Columbus Experiment Field, 1952.

Ser-ies	Depth (in.)	Per cent organic matter in various plots										
		1	2	3	4	6	7	9S	9N	10	11	12
A	0-6	1.67	1.75	2.20	1.86	1.87	1.97	2.12	2.25	1.90	2.14	2.07
	6-8	1.75	1.77	1.65	1.70	1.80	1.69	1.74	1.96	1.74	1.81	1.66
	8-10	1.25	1.50	1.70	1.70	1.48	1.50	1.39	1.69	1.30	1.40	1.40
B	0-6	1.63	1.76	1.93	1.82	2.07	1.88	2.00	2.07	1.96	1.95	1.90
	6-8	1.55	1.59	1.90	1.47	1.50	1.43	1.48	1.83	1.73	1.85	1.90
	8-10	1.26	1.12	1.46	1.28	1.31	1.33	1.55	1.60	1.41	1.58	1.69
C	0-6	2.04	2.00	1.98	1.95	2.05	2.14	1.91	1.97	1.64	1.68	1.60
	6-8	1.81	1.89	1.77	1.83	1.91	1.65	1.65	1.66	1.54	1.62	1.55
	8-10	1.41	1.68	1.57	1.54	1.53	1.33	1.27	1.43	1.30	1.21	1.34
D	0-6	1.84	2.09	2.05	2.03	2.46	2.26	2.18	2.26	1.81	1.96	1.76
	6-8	1.58	1.88	1.66	1.59	1.65	1.51	1.71	1.59	1.43	1.51	1.65
	8-10	1.46	1.35	1.32	1.24	1.40	1.64	1.32	1.33	1.10	1.24	1.36
E	0-6	2.08	1.84	1.97	1.95	2.15	2.24	2.19	1.98	1.78	2.01	1.77
	6-8	1.89	1.60	1.51	1.80	1.90	2.01	1.79	1.69	1.60	1.81	1.78
	8-10	1.52	1.17	1.25	1.55	1.65	1.52	1.45	1.20	1.46	1.50	1.43
F	0-6	1.64	1.60	1.78	1.84	1.97	2.10	2.16	2.09	1.80	1.77	1.69
	6-8	1.55	1.24	1.54	1.54	1.83	1.68	2.09	1.90	1.65	1.65	1.67
	8-10	1.47	1.19	1.31	1.38	1.55	1.27	1.75	1.63	1.45	1.59	1.38
AVERAGE OF ALL SERIES												
	0-6	1.81	1.84	1.98	1.90	2.09	2.09	2.09	2.10	1.81	1.91	1.79
	6-8	1.69	1.66	1.64	1.65	1.76	1.66	1.74	1.77	1.61	1.70	1.70
	8-10	1.39	1.33	1.43	1.44	1.50	1.43	1.45	1.48	1.33	1.42	1.43

Table 8. Total nitrogen content of various fertility plots at Columbus Experiment Field, 1952.

Series	Depth (in.)	Percent nitrogen in various plots										
		1	2	3	4	6	7	9N	9S	10	11	12
A	0-6	.0970	.0984	.0990	.1009	.1186	.1122	.1206	.1181	.0995	.1216	.1191
	6-8	.1000	.1000	.1030	.0990	.1060	.1009	.1060	.0090	.0990	.0910	.0984
	8-10	.0821	.0882	.0954	.0931	.0921	.0910	.0774	.0833	.0784	.0892	.0843
B	0-6	.0970	.0970	.1088	.1034	.1117	.1117	.1110	.1108	.0956	.1142	.1009
	6-8	.0892	.0910	.1009	.0833	.0910	.0941	.0961	.0892	.0954	.0990	.0725
	8-10	.0794	.0745	.0872	.0794	.0833	.0892	.0941	.0872	.0872	.0902	.0833
C	0-6	.1157	.1122	.1110	.1083	.1176	.1181	.1088	.1108	.0931	.1009	.0946
	6-8	.1009	.1030	.1040	.1050	.0990	.0872	.0921	.0910	.0821	.0921	.0843
	8-10	.0892	.0902	.0921	.0902	.0833	.0735	.0814	.0764	.0745	.0804	.0755
D	0-6	.1014	.1052	.1103	.1108	.1308	.1216	.1255	.1152	.0980	.1054	.0931
	6-8	.0970	.1040	.0931	.0941	.1009	.0970	.0881	.0961	.0843	.0921	.0910
	8-10	.0833	.0833	.0735	.0784	.0804	.0784	.0804	.0755	.0725	.0745	.0804
E	0-6	.1098	.1063	.1108	.1078	.1206	.1220	.1191	.1230	.0921	.1078	.0946
	6-8	.1050	.0961	.0921	.1040	.1078	.1088	.1008	.1009	.0902	.0990	.0960
	8-10	.0910	.0735	.0735	.0882	.0872	.0872	.0843	.0821	.0821	.0821	.0843
F	0-6	.0970	.0970	.0990	.0990	.1063	.1147	.1147	.1161	.0970	.0954	.0910
	6-8	.0975	.0784	.0862	.0954	.1009	.0961	.1040	.1070	.0941	.0931	.0872
	8-10	.0910	.0755	.0774	.0833	.0902	.0794	.0954	.0931	.0843	.0853	.0833
AVERAGE OF SERIES												
	0-6	.1030	.1027	.1065	.1050	.1176	.1167	.1167	.1157	.0960	.1075	.0989
	6-8	.0983	.0954	.0966	.0968	.1009	.0973	.0970	.0972	.0909	.0944	.0882
	8-10	.0843	.0809	.0832	.0854	.0861	.0831	.0855	.0829	.0798	.0834	.0819

indicate a soil variation running east to west through the field. Series C which has received a total of 4 1/2 tons of limestone per acre has remained the most acid, having a range in pH values in the surface 6 inches of soil of from 5.6 to 5.8 for the limed plots as compared to 5.1 for the unlimed soil. The same amount of limestone, 4 1/2 tons per acre, applied to series A and B has resulted in an average pH value for each series of 6.2. The unlimed plot of series A had a pH value of 5.3 while in series B it had a value of 5.4. Again a soil variation may be indicated, this time running across the field through series C.

It is of interest to consider the liming history of the field as shown in Table 2. Series A, B, and C have already been discussed, at least in part, from this viewpoint. It was observed that series B which last received limestone in 1935 currently has a pH range in the surface 6 inches of 5.9 to 6.4 for the limed plots as compared to 5.4 for the unlimed plot, a marked effect after 17 years.

Series D has received a total of 5 1/2 tons of limestone per acre, the last of which was applied in 1938. The surface 6 inches in this case has a range in pH values of from 6.1 to 6.4 for the limed plots as compared to 5.2 for the untreated.

Series E shows considerable variation for the 0-6 inch depth, the pH values of the limed plots ranging from 5.7 to 6.5 with an average value of 6.0. The unlimed plot has a pH value of 5.5. This series received a total of 6 tons of limestone per acre, the last application being 3 tons per acre in 1924.

Thus after 28 years there are still two plots, 10 and 11, that have satisfactory pH values by current standards.

Series F is of particular interest as regards soil reaction. A total of 9 tons of limestone per acre has been added to this series, 3 tons per acre in each of the years 1923, 1924, and 1925. The reason for this comparatively heavy application was not made clear in the early reports of the Southeastern Kansas Experiment Fields (1). The application in 1923 was made in preparation for alfalfa. An additional application was made in 1924, apparently just prior to seeding alfalfa. This may have been an oversight or may have been intentional, the records merely report the fact. The final 3 tons per acre applied in 1925 is equally inexplicable. At any rate the fact remains that 9 tons of limestone per acre have been added, the last application 27 years ago. This series presents a most striking demonstration of the long-time effect of lime; the range in pH values for the surface 6 inches being from 6.6 to 7.5 with an average value of 7.2 as compared to 5.2 for the unlimed plot.

Unfortunately no record of the $CaCO_3$ equivalent of the various applications of limestone was kept over the years so it has not been possible to evaluate the amounts added from this standpoint.

Other than the effect of limestone there was no indication that any of the other added materials had appreciably influenced soil reaction.

Available Phosphorus. Considering first the extraction in which a solution 0.1 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride was used (Table 4),

the plots which received rock phosphate gave extremely high values for available phosphorus, over 300 pounds per acre for the plots treated with rock phosphate as compared to about 40 pounds per acre for the various plots receiving superphosphate as part of the treatment. These high values for the plots which received rock phosphate were not considered valid from the standpoint of availability to plants. This has been borne out by yield data from the field; rock phosphate has ranked high among the treatments as regards total crop yield but in no case has rock phosphate outranked superphosphate by the margin that these soil tests would seem to indicate.

The second extraction, using a solution 0.025 N with respect to hydrochloric acid and 0.03 N with respect to ammonium fluoride, appeared to put the two carriers of phosphorus on a more equitable basis for comparison, one that was more in line with crop yield data. A study of Figures 2 and 3 reveals that, omitting the rock phosphate plots, all other treatments have maintained about the same relationship regardless of the extraction, although the values obtained from the weak acid extraction were generally lower. Criticism of the second extraction may be made in that it delegates rock phosphate to a position inferior to superphosphate whereas the yield data from the field reveals very little difference, at the rates used, in effectiveness with respect to increasing yields. While such criticism may well be valid, it was felt, that the weak acid extraction did permit a more accurate comparison of the two carriers of phosphorus than

did the strong acid extraction.

The accumulation of phosphorus has been greatest in the 0-6 inch layer. The lesser build up that has occurred in the 6-8 inch layer may well be attributable to mixing resulting from plowing. At the 8-10 inch depth the values were quite uniform across the treatments. This would indicate that movement into this layer has been insignificant.

Plot 9, which was split in 1947 into 9N and 9S, 9N to continue receiving rock phosphate when due, 9S to receive no additional rock phosphate, revealed something of the residual effect of rock phosphate. Under the strong acid extraction the average values for all series were 331 pounds for the residual plot and 334 pounds for the half continuing to receive rock phosphate. Under the weak acid extraction the residual plot had a value of 17.1 pounds, the other 14.8 pounds. The figures which made up these averages were themselves quite erratic. Series A had not received any rock phosphate since 1947 yet there was a 30 pound advantage in favor of 9N by the strong acid extraction and a 5 pound advantage by the weak acid extraction. Series E and F, each of which had received an application of 1000 pounds of rock phosphate per acre since 1947, both revealed the residual plot as having the greatest available phosphorus by either extraction.

Yield data tended to agree with the overall picture, namely that for the 5 years that have elapsed there had been no noticeable decline in phosphorus response on plot 9S as compared to 9N.

Plot 10 which had never had a legume in the rotation had the

second highest value by the weak acid extraction. This accumulation was directly attributable to the absence of alfalfa which was a heavy user of phosphorus. In spite of this build up of phosphorus plot 10 ranked above only the no treatment plots in regard to the production of all crops in the five year rotation, possibly indicating that phosphorus had not been the limiting factor in this case.

Exchangeable Potassium. Figure 4 reveals some interesting aspects of the potassium situation. The highest values for potassium were found on plots 6, 7, 9S, 9N, all plots having had manure as part of their treatment. Plot 3, the only plot receiving potash did not quite come up to the level of the manured plots in exchangeable potassium. From this it may be inferred that at the rates used barnyard manure had been at least as effective as a carrier of potassium as had muriate of potash.

A study of the results for the individual plots (Table 6) reveals a rather erratic distribution of potassium thru the three depth considered. In series D the upper 6 inches was generally higher in potassium; in series F the 6-8 inch and 8-10 inch depths were the higher. For the average of all series the 0-6 inch depth was found to have the highest values in six cases; the 6-8 inch depth being highest in the remaining five plots.

According to the latest standards accepted for the Kansas soil testing program all of the plots would be considered deficient in potassium for some if not all crops. Considering with

this the fact that crop response to potash was very limited on this field in the early years but had shown definite signs of increasing in the later years, following the increase in amount of potash applied, it seemed valid to infer that the rate of potash application had not yet reached the optimum.

Organic Matter. The organic matter picture as revealed by Fig. 5 shows the manured plots to be slightly, but definitely, higher in organic matter than the other plots as regards the surface 6 inches. For the other depths the values were quite uniform irregardless of treatment. This would conform to the expected relationship of organic matter to depth.

Plot 10 which had never grown a legume was lower in organic matter than all but the no treatment plots. This was in part attributable to the absence of alfalfa; with redtop or bromegrass substituted for alfalfa considerably less material had been returned to the soil than on plots which did have alfalfa.

That the no treatment plots were lowest in organic matter was the result of the generally lower fertility level of these plots with the correspondingly low crop production resulting in less crop residues.

While the build-up of organic matter on the manured plots only averaged about 0.2 per cent over the unmanured plots the yield data had consistently shown the manured plots to be the leaders in crop production to an extent that throws a greater stress on a 0.2 per cent increase in organic matter than might at first be suspected.

Table 9 shows the treatments ranked according to yield of

all crops in the 5-year rotation for a 19 year period as presented by Davidson and Smith (6). A weighted average of all crops in the 5 year rotation with no treatment set at 100 had been used. The average values in the surface 6 inches for each treatment over all series was listed for phosphorus, potassium, organic matter, and nitrogen. These figures have been ranked with 1 as the highest. It will be observed that per cent organic matter ranks the treatments in the same order as does crop yield except for the ties at positions 2 and 6. This represents a much higher degree of correlation than was found between crop yield and any of the other factors considered.

Total Nitrogen. In general the situation as regards nitrogen would appear closely allied with the organic matter content. Percentagewise the differences between highest and lowest values were smaller in the case of nitrogen, about 0.02 per cent as compared to about 0.2 per cent in the case of organic matter. The drop in nitrogen content with increasing depth was even more pronounced than was the drop in organic matter content. Again the manured plots gave the highest values and plot 10 with no legume the lowest. In the matter of rank as shown in Table 9 the order was not as well defined for nitrogen as it was for organic matter. However the three treatments containing manure did form a top class.

Table 9. A comparison of the chemical composition of the Columbus fertility plots with respect to yield of all crops.

Treatment	Comparative percentage* (Av. all crops)	Phosphorus		Potassium		Organic matter		Total nitrogen	
		lbs/ acre	rank	lbs/ acre	rank	%	rank	%	rank
Lime, manure, and rock phosphate	176	17.1	3	110	4	2.10	1	.1162	3
Lime, manure, and super phosphate	174	22.7	1	116	2	2.08	2	.1167	2
Lime and manure	167	15.2	5	136	1	2.09	2	.1176	1
Lime, superphosphate, and potash	162	14.8	6	112	3	1.98	3	.1065	4
Lime and rock phosphate	157	12.4	7	105	5	1.90	4	.1050	6
Lime and superphosphate	156	16.0	4	90	7	1.87	5	.1051	5
Lime	139	8.0	8	92	6	1.81	6	.1030	7
Lime and superphosphate (no legume)	136	21.9	2	92	6	1.81	6	.0960	9
No treatment	100	7.9	9	90	7	1.79	7	.0989	8

*Based on weighted average of yield of all crops in the 5 year rotation, no treatment rated as 100 per cent, 1931-49.

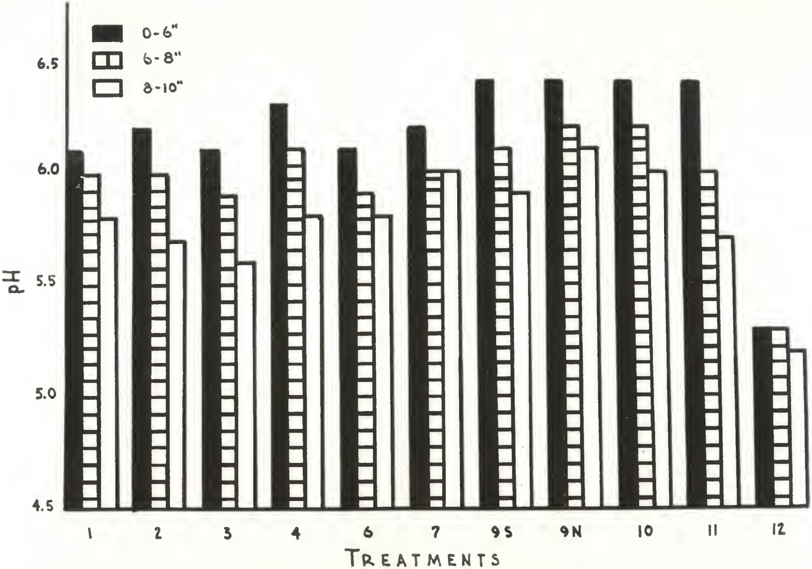

FIG. 1. pH OF 1:1 SUSPENSION. AVERAGE OF ALL SERIES

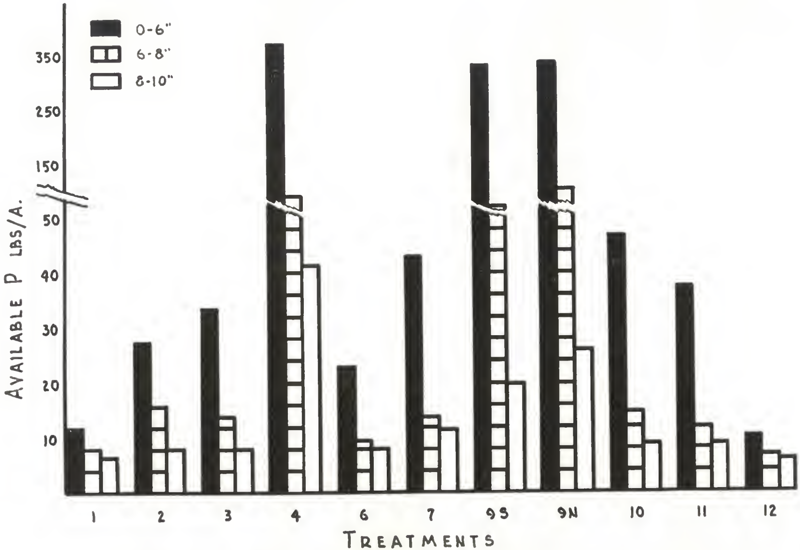

FIG. 2. POUNDS OF AVAILABLE PHOSPHORUS PER ACRE, USING 0.1 N HCL AND 0.03 N NH_4F. AVERAGE OF ALL SERIES

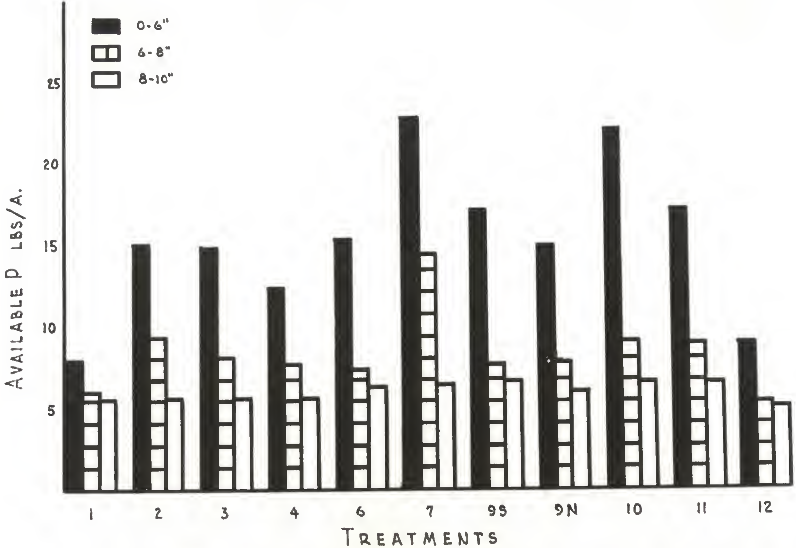

Fig. 3. Pounds of available phosphorus per acre, using 0.025N HCl and 0.03N NH_4F. Average of all series

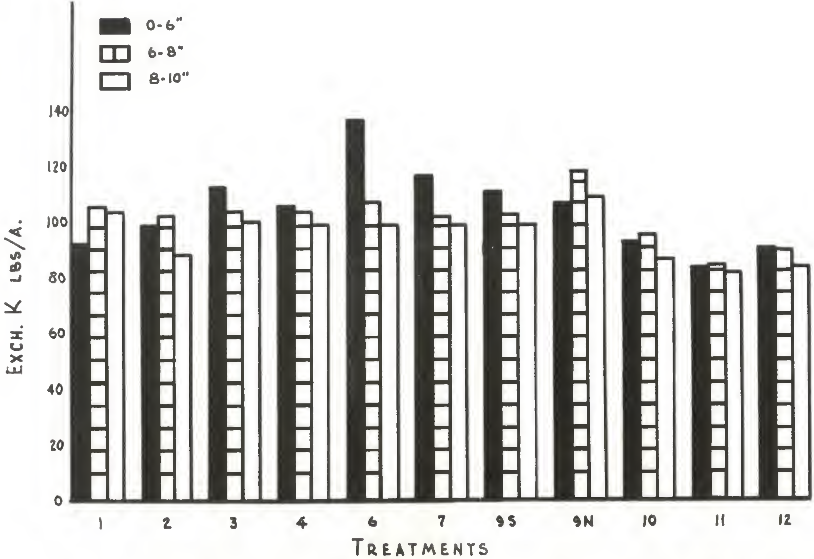

FIG. 4: POUNDS OF EXCHANGEABLE POTASSIUM PER ACRE. AVERAGE OF ALL SERIES

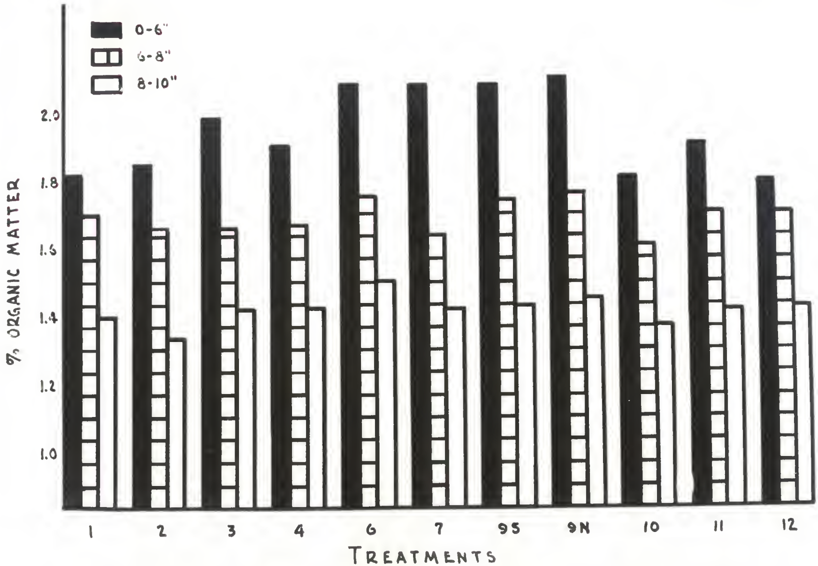

FIG. 5. ORGANIC MATTER CONTENT (%). AVERAGE OF ALL SERIES

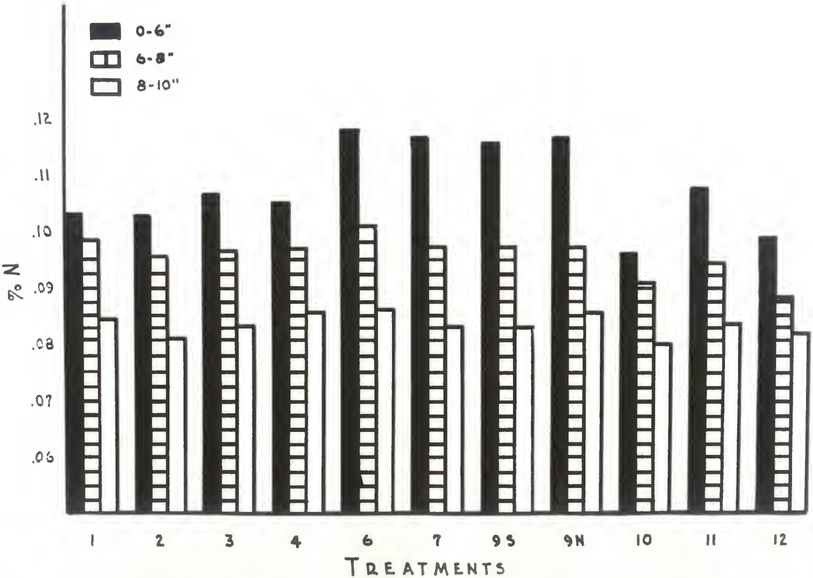

FIG. 6. TOTAL NITROGEN CONTENT (%). AVERAGE OF ALL SERIES

GREENHOUSE STUDY

Plan of the Experiment

A pot experiment was carried out in the greenhouse in an effort to learn something more of the phosphorus status of soils that had been receiving superphosphate or rock phosphate during the years of the experiment at the Columbus field.

Soil from plot A-2, a lime and superphosphate plot, and from plot A-4, a lime and rock phosphate plot, were used. The soil samples were tabled, mixed and weighed into earthenware crocks at the rate of 4000 grams per pot. The 4000 gram samples were again tabled and nitrogen in the form of ammonium nitrate at the rate of 166 pounds per acre and potassium in the form of 60 per cent muriate of potash at the rate of 250 pounds per acre was added and thoroughly mixed with the soil. This treatment was given to all pots. In addition phosphorus in the form of $Ca(H_2PO_4)_2$ was added at various rates to the pots assigned the particular treatments. Commercial rock phosphate at the rate of 2 tons per acre was similarly added to the pots scheduled for that treatment. Each treatment was repeated 3 times for each of the 2 soils. Three pots of each soil were given no added phosphorus. These served as controls. The treatments then were:

0 ppm added P
10 ppm added P
20 ppm added P
40 ppm added P
80 ppm added P
160 ppm added P
Rock phosphate - 2 tons per acre

A spring wheat, Pusa 52 x Federation, was planted on November 10, 1952. The pots were laid out on the greenhouse bench in a completely randomized design. On November 22 the stand was reduced to ten plants per pot.

The crop was grown to maturity, allowed to ripen and harvested on February 26, 1953. The harvested material was oven dried at 80 degrees centigrade for 72 hours. The straw and heads were then weighed separately. The heads were threshed and the weight of grain taken. The difference between grain weight and head weight, representing the weight of chaff, was added to the straw weight. These data are recorded in Tables 10 and 11.

Plant Tissue Analyses

The plant material was ground in a Wiley Mill using a number 40 sieve. The ground material was then subjected to further oven drying for 48 hours at 105 degrees centigrade. After the drying period duplicate 0.2 gram samples were taken and prepared for analysis. A wet ashing process using magnesium nitrate in alcohol was employed. The material was ignited in an electric muffle furnace for a period of two hours at 550 degrees centigrade. The residue was taken up in 2 N hydrochloric acid, filtered and diluted to 100 ml volume.

For the determination of phosphorus a modification of Bray's sulfonic acid reduction method was used. A 25 ml aliquot was taken, neutralized with 0.2 N NaOH to the phenolthalien end

Table 10. The effect of various phosphorus treatments on yield and phosphorus content of wheat grown on a soil having a 26 year history of superphosphate applications.*

Treatment	Total dry matter grams	Straw grams	Grain grams	Phosphorus content Percent grain	straw	Phosphorus content mgs grain	straw	Total
0 ppm P	13.53	9.06	4.47	.3642	.0592	1629	536	2165
10 ppm P	12.26	8.53	3.72	.3484	.0661	1296	564	1860
20 ppm P	10.42	7.28	3.14	.3254	.0702	1022	511	1533
40 ppm P	11.54	7.68	3.85	.3805	.0941	1465	723	2188
80 ppm P	11.93	8.05	3.88	.3438	.1374	1334	1105	2439
160 ppm P	13.16	9.20	3.95	.3534	.2000	1395	1840	3235
Rock (2 tons per acre)	10.42	7.16	3.25	.3500	.1100	1137	788	1925

*This soil has received, since 1926, 344 pounds of P_2O_5 per acre.

Table 11. The effect of various phosphorus treatments on yield and phosphorus content of wheat grown on a soil having a 26 year history of rock phosphate applications.*

Treatment	Total dry matter grams	Straw grams	Grain grams	Phosphorus content Percent grain	straw	Phosphorus content mgs grain	straw	Total
0 ppm P	8.87	6.29	2.57	.2858	.1333	734	838	1572
10 ppm P	10.55	7.92	2.61	.3725	.1260	972	998	1970
20 ppm P	8.94	6.58	2.36	.3529	.1481	833	975	1808
40 ppm P	10.66	8.19	2.47	.4063	.1347	1004	1103	2107
80 ppm P	9.60	6.90	2.69	.3642	.1310	980	904	1884
160 ppm P	11.26	7.91	3.35	.3963	.1305	1328	1032	2360
Rock (2 tons per acre)	7.52	5.93	1.59	.3270	.0632	520	375	895

*This soil has received, since 1926, 5,000 pounds of rock phosphate per acre.

point and diluted with distilled water to 50 ml volume. To this was added 2 ml of ammonium molybdate-hydrochloric acid solution and 2 ml of Bray's sulfonic acid reducing agent. Color was allowed to develop for 15 minutes. The per cent transmission was then read on the Evelyn photoelectric colorimeter using a 660 mu filter. A calibration curve was prepared from solutions of known phosphorus content which had received the same treatment as the samples. From the calibration curve the galvanometer readings obtained for the samples were converted to ppm phosphorus.

Discussion of Greenhouse Results

It was desired in this experiment:

1. to compare, from the standpoint of available phosphorus, a soil having a long history of superphosphate treatment with a soil having an equally long history of rock phosphate treatment.

2. to determine the effect of added increments of a readily available form of phosphorus on the phosphorus uptake from each of the soils studied.

Yield data. The yield data are presented in Tables 10 and 11. From the data the soil from plot A-2, (superphosphate history) appears to be superior to the soil from plot A-4 (rock phosphate history). This was true both from the standpoint of total dry matter produced and grain produced.

During the growth of the crop it was apparent that the plants on the soil from plot A-2 had a faster rate of growth, matured

earlier and ripened a week to ten days earlier than those grown on the soil from plot A-4.

There was no evidence of increased yield from any treatment on the soil from plot A-2. Where rock phosphate was added there was a suppression of yield as compared to no treatment.

The soil from plot A-4 did show some slight increases in yield from the added increments of available phosphorus. Here again there was suppression of yield where rock phosphate was added.

Phosphorus Uptake. Tables 10 and 11 show phosphorus uptake for grain and straw in per cent and in milligrams. Total uptake is also given in milligrams.

Plants grown on the soil from plot A-2 showed very little difference percentagewise in phosphorus content of the grain. However the per cent phosphorus in the straw increased at the higher levels of added phosphorus. Total uptake, which seemed to be most influenced by the increases occurring in the straw, followed a similar trend, increased uptake at the higher levels.

The picture was somewhat reversed in the case of the plants grown on the soil from plot A-4. Here the phosphorus content of straw was extremely uniform at all levels of added available phosphorus. Where rock phosphate had been added the phosphorus content of straw was about half of that resulting from no treatment.

The per cent phosphorus in grain showed increases with all treatments, including rock phosphate.

Considering total uptake there were increases from all treatments except rock phosphate.

Conclusions

The indications were that the soil from plot A-2 was already at a satisfactory phosphorus level. Addition of a readily available form of phosphorus at this point did not materially affect yield, it was reflected chiefly in increased phosphorus content of the straw.

It would appear that phosphorus was less available to plants on soil from plot A-4 than on soil from plot A-2. Slight increases, both in yield and in total uptake, resulted from the various increments of added available phosphorus in the case of the soil from plot A-4.

The suppression in yield and in uptake that resulted from the addition of rock phosphate cannot be explained readily.

In spite of the long history of rock phosphate applications this soil does not appear to have reached a satisfactory phosphorus level insofar as availability to wheat is concerned. One factor worthy of consideration is the pH of this soil. Plot A-4 had a pH value of 6.2. It has been rather well established that the availability of rock phosphate is greatest at more acid values. As a further study it would be of interest to acidify the soil from plot A-4 than to carry out a greenhouse experiment similar to that herein reported.

SUMMARY

1. The lasting effect of lime in altering the soil reaction was clearly indicated. This effect was apparent to a depth of approximately 10 inches.

2. Essentially no movement of phosphorus below the plow depth was found. There has been no large increase in available phosphorus resulting from long-time applications of superphosphate. However, greenhouse data revealed such a soil to have no pronounced phosphorus deficiency.

3. At the rates used during the history of the field there had been no large accumulation of potassium. Greater accumulation had resulted from applications of barnyard manure than from applications of a very small amount of muriate of potash.

4. The manured plots averaged 0.2 per cent higher in organic matter content than did the unmanured. When correlated to yield data this small per cent was found to be quite significant. Rank of treatments according to content of organic matter in the soil corresponds exactly with rank according to yields.

5. Nitrogen content followed essentially the same pattern as organic matter content, the difference being in plot 10 which had never grown a legume. This plot was markedly lower in nitrogen content than any other plot.

6. In general the nutrient status of these soils, as revealed by chemical analyses, had improved under the various treatments in comparison with no treatment. The treatments lime, rock phosphate and manure; lime, superphosphate and manure; and lime and

manure consistently showed the most desirable level of each of the factors considered. These were the treatments that consistently led in crop production.

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THE NUTRIENT STATUS OF A CHEROKEE SILT LOAM SOIL AFTER LONG-TIME APPLICATION OF FERTILIZERS, LIME, AND MANURE

by

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A laboratory and greenhouse study of the soils from the Columbus Fertility Plots in southeastern Kansas was undertaken in an effort to learn something of the nutrient status of these soils after 28 years of fertilizer, lime and manure treatments.

Soil samples were taken from 0-6", 6-8", and 8-10" depths from each of the plots. The following chemical analyses of these samples were made in the laboratory:

1. pH of 1:1 suspension
2. available phosphorus
3. exchangeable potassium
4. organic matter content
5. total nitrogen content

For the greenhouse study soil from two of the plots was used: one having a history of lime and superphosphate applications, the other a history of lime and rock phosphate applications. Spring wheat was grown in a pot experiment in which the treatments consisted of the addition of various levels of a readily available form of phosphorus. The crop was grown to maturity. Yield data were taken. The grain and straw were analyzed for phosphorus content.

The results of the chemical analysis revealed the long time effect of lime in raising the pH of the soil. The effect was noticeable through the three depths studied.

Two phosphorus extractions were made: one, using a strong acid, gave values for the rock phosphate treated plots that were considered too high from the standpoint of availability to plants; the other, using a weak acid, appeared to put rock phosphate

treated plots on a more equitable basis for comparison with superphosphate treated plots.

The movement of phosphorus appeared to have been limited to the plow layer, the 8-10 inch depth being quite uniform regardless of treatment.

Exchangeable potassium has not accumulated to any great extent on the potash treated plots, probably due in part, to the relatively light applications of potash that have been made. Plots having manure as part of their treatment were consistently at a higher potassium level than were the potash treated plots.

In the surface 6 inches the manured plots were slightly higher in organic matter content than were the unmanured plots. Values at the other depths were quite uniform regardless of treatment.

A ranking of treatments based on organic matter content agrees perfectly with a ranking based on yield of all crops for a nineteen year period.

The nutrient status of these soils appears to have been improved under the various treatments as compared to no treatment. Long-time yield data reveal the treatments that include manure to be the leaders in crop production .